Population Characteristics and Management of Black Bass in Eastern Oklahoma Streams

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Abstract: We surveyed black bass (*Micropterus* spp.) populations in Baron Fork in northeastern Oklahoma and Glover River in southeastern Oklahoma during 1994 and 1995 to assess population characteristics and management options particularly for smallmouth bass *(M. dolomieu)* in eastern Oklahoma streams. Smallmouth bass dominated the catch of black bass species in both streams during both years. The fishery potential for smallmouth bass in Glover River was limited in part by low abundance, poor year-class success, and high annual mortality resulting in low recruitment to older ages. In contrast, smallmouth bass in Baron Fork were abundant, exhibited good year-class success, and low annual mortality. Growth of early-age smallmouth bass was similar between streams. These differences in population characteristics may be attributable in part to the stable flow regime and nutrient enrichment from agricultural activities in Baron Fork compared with the flashy flow regime and sedimentation from silviculture activities in Glover River. Management of smallmouth bass and other black bass populations in eastern Oklahoma streams will require a combination of regionally-specific harvest regulations, stream habitat restoration projects, and improved watershed management practices to maintain and enhance these fishery resources.

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Stream fisheries in Oklahoma have received little management compared to reservoir fisheries (Fisher et al. 1997), partly because of a paucity of information on stream fish populations and the limited geographic extent of accessible, high-quality, free-flowing streams, most of which are in the eastern part of the state. Surveys of

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sport fish populations in eastern Oklahoma streams by Jenkins et al. (1952), Finnell et al. (1956), Smith (1982), and Orth et al. (1983) have provided important historical information. A geographically extensive survey of black bass at 62 sites in 21 streams by Stark and Zale (1991) revealed significant differences between populations in northeastern and southeastern Oklahoma streams. They concluded that stream fisheries in these 2 regions may require different management strategies because of differences in black bass population characteristics. However, their survey was conducted during only 1 year and, consequently, did not assess interannual variation between populations.

Of the 3 black bass species [smallmouth bass, largemouth bass *(M. salmoides),* and spotted bass *(M. punctulatus)*] that occur in Oklahoma streams, smallmouth bass have been studied most extensively. Smallmouth bass reach the southeastern extent of their native range in eastern Oklahoma (MacCrimmon and Robbins 1975). Recently, Stark and Echelle (1998) identified genetically distinct stocks of this species in northeastern (Ozark Highlands) and southeastern (Ouachita Highlands) Oklahoma streams. These stocks have been reported to have both similar and different growth rates, abundances, and age and size structures. Orth et al. (1983) found that the growth rates of smallmouth bass in Glover River in southeastern Oklahoma were comparable to those in nearby rivers (Finnell et al. 1956) and in a northeastern Oklahoma river (Leonard and Jenkins 1952) but slower than those found in larger rivers and reservoirs. Stark and Zale (1991) found low numbers of relatively fast-growing smallmouth bass in southeastern Oklahoma streams, but recruitment was poor. In contrast, they reported high abundances of this species with reduced growth rates and inconsistent recruitment in most northeastern Oklahoma streams. Although Stark and Zale (1991) developed management recommendations for smallmouth bass in these regions, more information was needed about the dynamics and exploitation of these populations before their recommendations could be implemented.

We surveyed black bass in 2 eastern Oklahoma streams over 2 years to assess differences in population characteristics. Our specific objectives were to (1) compare abundance of 3 black bass species, and age and size structure, growth and mortality rates, and condition of smallmouth bass in a northeastern (Baron Fork) and southeastern (Glover River) Oklahoma stream, and (2) use this information to assess the fishery potential and management options for black bass, particularly smallmouth bass, in eastern Oklahoma streams.

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Methods

Study Area

Baron Fork and Glover River are state-designated scenic rivers in eastern Oklahoma. Baron Fork is a 57-km tributary of the Illinois River located in the Ozark Highlands of northeastern Oklahoma and has a drainage area of 936 km^2. It is characteristic of streams in this region with clear, cool ($\bar{x}=16.4$ C ±4.98 SD in 1994–1995), hard (range=60–99 mg/liter $CaCO^3$) water that drains chert and limestone rocks (Marcher 1969); a gravel-dominated substrate; and relatively stable flows ($\bar{x}=10.62$ m^3/sec 177% CV in 1994–1995) maintained by numerous springs. Forests (54%) and pastures (44%) cover the landscape, and agriculture, including numerous confirmed poultry operations (Nolan et al. 1989), is the predominant land use activity. Glover River is a 54-km tributary of the Little River located in the Ouachita Highlands of southeastern Oklahoma and has a drainage area of 876 km^2. It is typical of streams in this region with warm ($\bar{x}=18.2$ C ± 6.80 SD in 1994–1995), moderately turbid, soft (range=12–38 mg/liter $CaCO^3$) water that drains shale and sandstone rocks (Marcher and Bergman 1983); a substrate dominated by bedrock and emergent boulders; and relatively flashy flows ($\bar{x}=12.91$ m^3/sec, 234% CV in 1994–1995) fed primarily by runoff. The watershed is heavily forested (92%) and dominated by intensive silviculture activities (Rutherford et al. 1987).

Fish Sampling

We chose sampling sites along a 16.7-km segment of Baron Fork and a 38.6-km segment of Glover River. To minimize sampling bias (Balkenbush and Fisher 1997), we randomly selected sites from both easily accessible public areas and less accessible remote areas. Our sampling sites included 2 remote areas and 2 public areas each on Baron Fork and Glover River. Each site consisted of a pool bordered by riffles or low-water bridges at one or both ends. In Baron Fork, sites averaged 69 m in width and 664 m in length, and in Glover River, they averaged 112 m in width and 386 m in length. Detailed site descriptions are given in Balkenbush (1996). Sampling occurred from August through October of 1994 and 1995 when the streams were at or near base flow.

Fish were collected by electrofishing with pulsed direct current using a boat equipped with a Smith-Root 3.5 GPP electrofisher, generator, and bow-mounted boom with a ring electrode. Before electrofishing, each site was isolated at the upstream and downstream ends with 55 mm × 1.8 mm × 12.7-mm^2 mesh nets to prevent fish movement in and out of the sample area. Two electrofishing runs were made through each site, one to mark fish and the other to recapture marked fish. Following the first electrofishing (marking) run, all captured fish were marked (partial caudal fin clip), and lengths (mm), weights (g), and scale samples were taken for age and growth, mortality, and condition analysis. Scale samples were not collected from fish visually determined to be young-of-year. When large numbers of fish were captured, scale samples were taken from a subsample of fish (at least 2 fish from each 20-mm length group). Fish were released back into the enclosed area after processing and left undisturbed for about 2 hours to allow for dispersal. After the second electrofishing (recapture) run, fish were examined for marks, and lengths (mm), weights (g), and scale samples were collected from unmarked individuals. Otoliths were taken from a subsample of sacrificed fish. Following sampling, the area of each site was calculated by multiplying the mean stream width between the block nets by the site length. Total number of fish captured and number of marked fish recaptured were recorded for population estimates.

Data Analysis

Fish captured from sample sites in each stream were pooled to estimate population size. We pooled these collections because small sample sizes and low recapture rates precluded us from calculating estimates at several sites. Population estimates for smallmouth bass, largemouth bass, and all black bass species in aggregate were calculated using the Chapman modification (Chapman 1951) of the Petersen estimate (Ricker 1975). Approximate confidence limits using either a Poisson, binomial, or normal distribution were calculated, when possible, following the methods of Seber (1982). We calculated age-specific population estimates of smallmouth bass by multiplying the proportion of the sample each age group represented (determined from the length frequency histograms) by the total population estimate (Bovee et al. 1994). Density (*N*/ha) was then estimated by dividing the population estimate by the area sampled in each stream. We estimated biomass (kg/ha) for each age group by multiplying density by the mean weight of the group.

Scales collected from smallmouth bass were used for age and growth analysis. Scales, taken posterior to the tip of the pectoral fin and below the lateral line (Ambrose 1983), were impressed onto cellulose acetate slides and viewed with a scale reader at 40× magnification. The focus, annuli, and anterior edge of each scale were traced onto a paper strip and these tracings were measured on a digitizing tablet; length histories and annual growth increments were back-calculated with the DisBCal89 1.0 software program (Frie 1982). This program uses the Fraser-Lee method for back-calculating lengths at age. Scale samples from both years were pooled by species to back-calculate lengths at age. We were unable to verify our age determinations with otoliths because the otolith samples disintegrated.

Wilcoxon tests for 2 random samples (normal approximation; $P<0.05$; Zar 1984) were used to test for significant differences between growth histories of fish in Baron Fork and Glover River when sample sizes were 5 or more fish in each age class. Small sample sizes and regenerated scales precluded statistical testing of several age classes.

Total annual survival and mortality rates were calculated using the minimum-variance unbiased estimator (Chapman and Robson 1960, Everhart et al. 1975). This method assumes equal recruitment and constant survival in a population. Catch curve analysis revealed gear selectivity against age-0 fish, which were consequently excluded from the analysis.

Differences in body condition were assessed by comparing the slopes of length-weight regression lines with analysis of co-variance (Zar 1984). We used predicted weight instead of original weight because the former represents an average response weight for any length. A regression of $\log_{10}$-transformed total length (mm) versus $\log_{10}$-transformed weight (g) was calculated for each stream and year and was used to predict weight from the original length measurements. Pairwise linear contrasts were used to compare the slopes of the regression equations. If the slopes were parallel lines (i.e., both samples had similar weight increase per unit of length), a parallel lines model was used to test if the regression lines were significantly different (i.e., at any length, fish from one sample were heavier than the other). If the slopes were not parallel, a non-parallel lines model was used to compare the weights at stock-, quality-, and preferred-length, as defined by Gablehouse (1984).

Results

Abundance

A total of 376 black bass were captured from Baron Fork and Glover River. Smallmouth bass dominated the catch in each stream during both years, followed in order by largemouth bass and spotted bass in Baron Fork, and spotted bass and largemouth bass in Glover River (Table 1). For both years, black bass were more dense and had greater biomass in Baron Fork than in Glover River. Although black bass in Baron Fork were 32% more dense in 1995 than in 1994, total biomass was lower due to the large number of older smallmouth bass in the 1994 samples (Table 2). A similar

Table 1. Catch per unit effort (CPUE), density (95% Cl in parentheses), and biomass of black bass species in Baron Fork and Glover River, Oklahoma, 1994 and 1995.

Species	CPUE (*N*/hour)	Density (*N*/ha)		Biomass (kg/ha)
Baron Fork, 1994				
Smallmouth bass	12.89	115	(44–164)	18.99
Largemouth bass	6.81	36	(25–65)	10.72
Spotted bass	0.55			
All black bass	20.25	146		30.95
Baron Fork, 1995				
Smallmouth bass	18.85	98	(43–103)	26.45
Largemouth bass	13.37	87	(53–218)	9.71
Spotted bass	3.10			
All black bass	35.32	215		13.29
Glover River, 1994				
Smallmouth bass	6.49	52	(11–62)	4.48
Largemouth bass	2.30			
Spotted bass	3.97			
All black bass	12.76	118		10.97
Glover River, 1995				
Smallmouth bass	8.28	171	(39–233)	8.9
Largemouth bass	0.20			
Spotted bass	3.03			
All black bass	11.51	217		11.29

Table 2. Density and biomass of age classes of smallmouth bass in Baron Fork and Glover River, Oklahoma, 1994 and 1995.

Age	Density (*N*/ha)	Biomass (kg/ha)
Baron Fork, 1994		
0	26	0.23
1	32	1.25
2	25	3.18
3	20	6.64
4+	12	7.69
Baron Fork, 1995		
0	3	0.01
1	48	1.49
2	29	3.39
3	10	4.06
4+	8	4.34
Glover River, 1994		
0	15	0.09
1	32	1.41
2+	5	2.98
Glover River, 1995		
0	113	0.79
1	34	2.79
2	21	4.31
3+	3	1.01

trend was apparent in Glover River in 1995 when density estimates were about one-third more than those during the previous year, but total biomass estimates were nearly equal.

Smallmouth bass density in Baron Fork was over twice that in the Glover River in 1994 but only about two-thirds that in 1995 (Table 1). The Baron Fork population consisted of older fish, resulting in total biomass estimates that were 4 times greater than those from Glover River in 1994 and 1.5 times greater in 1995. Total density of smallmouth bass in Baron Fork was similar between 1994 and 1995; however, total biomass was higher in 1994 due to the prevalence of age-3 and older fish. Conversely, high catch rates of age-0 and age-2 and older fish caused 1995 smallmouth bass densities in Glover River to be 3 times higher than in the previous year. Total biomass of smallmouth bass in Glover River was similar between the 2 years because the large number of age-0 fish in 1995 did not contribute substantially to the biomass (Table 2).

Age and Growth

We aged scales from 90 smallmouth bass from Baron Fork and 29 from Glover River. The maximum age of smallmouth bass was 6 years in Baron Fork and 5 years in Glover River (Table 3). Most of the fish (93%) in Baron Fork were age 5 or less, and only 2 fish in Glover River were older than age 3.

Mean back-calculated lengths for age-1 and age-2 smallmouth bass were not significantly different between Baron Fork and Glover River (Table 3). Age-3 and

Table 3. Mean back-calculated total lengths (mm) ± SD for age classes of smallmouth bass from Baron Fork and Glover River in eastern Oklahoma.

	Mean ±SD back-calculated total length at age *(N)*						
Stream, state	1	2	3	4	5	6	Source
Baron Fork, Okla.	89 ± 18A[a] (85)	161 ± 28A (51)	228 ± 36 (32)	282 ± 36 (32)	357 ± 34 (4)	388 (1)	This study
Glover River, Okla.	91 ± 12A (26)	168 ± 25A (12)	239 ± 14 (4)	299 (1)	360 (1)		This study
Oklahoma Streams							
Baron Fork, Okla.	95	187	242	273	296		Stark and Zale (1991)
Illinois River, Okla.	90	177	242	310			Calander (1977)
Glover River, Okla.	92	161	216	247	300	342	Orth et al. (1983)
Mountain Fork River, Okla.	120	203	258	297	341	411	Stark and Zale (1991)
Regional Streams							
Tennessee River, Ala.	98	179	273	367	437	489	Weathers and Bain (1992)
Big Buffalo Creek, Mo.	78	134	183	233	278	321	Reed and Rabeni (1989)

a. Means followed by the same letter are not significantly different ($P > 0.05$)

older fish in Glover River were longer than those in Baron Fork, but small sample sizes in Glover River precluded statistical analysis. Smallmouth bass in both streams reached stock size (180 mm; Gablehouse 1984) between age 2 and 3, and were quality length (280 mm) near the end of their fourth growing season. Fish of preferred lengths (350 mm) were rare in our samples and consisted of age-5 and older individuals.

Mortality and Condition

Total annual mortality of smallmouth bass on Baron Fork varied annually from 47% in 1994 to 56% in 1995. In Glover River, smallmouth bass mortality was 88% in 1984 and 68% in 1995.

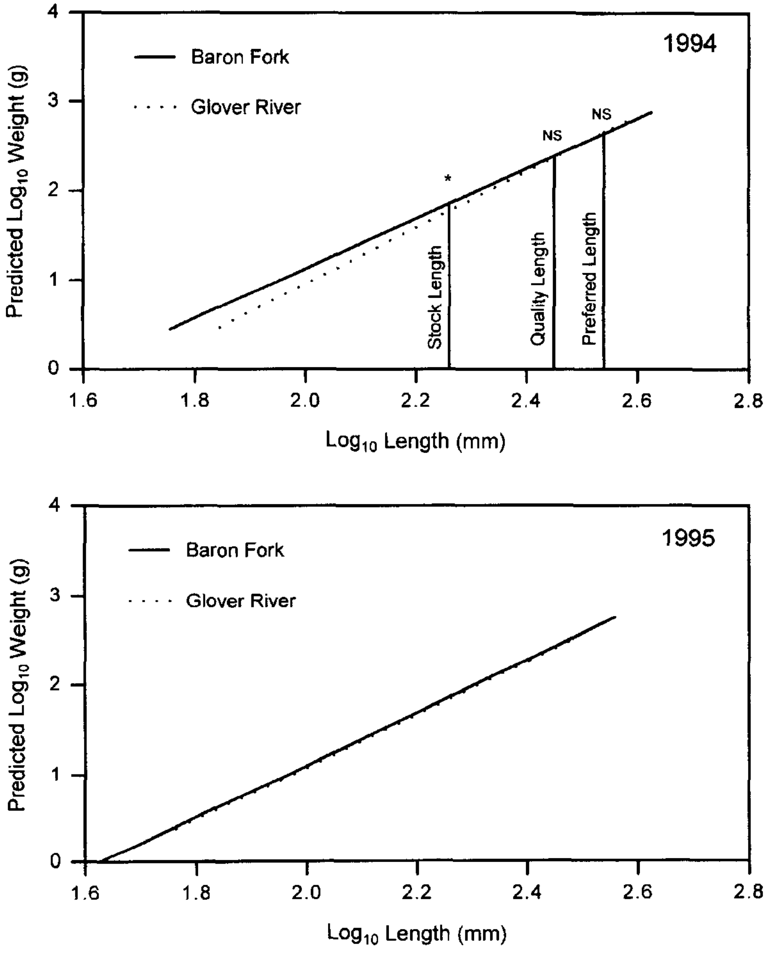

Figure 1. Relation between log length (mm) and predicted log weight (g) for smallmouth bass collected from Baron Fork and Glover River in 1994 (top) and 1995 (bottom). Asterisk denotes the 2 lines differ significantly (analysis of covariance test; $P < 0.05$).

We found no significant change in the condition of smallmouth bass between 1994 and 1995 in either Baron Fork or Glover River (Fig. 1). However, smallmouth bass in Baron Fork were significantly heavier ($P<0.05$) at stock length than those in Glover River in 1994 (Fig. 1). As fish length increased to quality and preferred categories, fish weight was essentially the same between streams. In 1995, the condition of smallmouth bass in both streams was nearly identical (Fig. 1).

Discussion

Abundance

Smallmouth bass dominated the black bass catch in Baron Fork and Glover River in our 1994–1995 survey. Previous studies of black bass in eastern Oklahoma streams suggest that dominance, in terms of abundance, of any one species may change over time. For example, surveys of black bass in northeastern Oklahoma streams were dominated by smallmouth bass in the early 1950s (Jenkins et al. 1952), spotted bass in the early 1980s (Smith 1982), and smallmouth bass again in the late 1980s (Stark and Zale 1991). Similarly, surveys of southeastern Oklahoma streams were dominated by smallmouth bass and largemouth bass in the mid 1950s (Finnell et al. 1956) and spotted bass in the late 1980s (Stark and Zale 1991). These changes in relative abundance of black bass species, however, may be attributable to differences in sampling gear and effort rather than a true shift in dominance, although this needs further study.

Our density and biomass estimates for smallmouth bass differed between years, especially in Glover River (Table 1), indicating variation in year class success that is typical of smallmouth bass populations (Cleary 1958, Pflieger 1975). Similarly, Stark and Zale (1991) found few large adults in Glover River and speculated that harsh environmental conditions in southeastern Oklahoma contributed to low recruitment and a marginal fishery for this species. In northeastern Oklahoma streams, Stark and Zale (1991) reported large numbers of younger-age fish and an uneven age distribution. However, we found smallmouth bass to have a relatively stable age distribution in Baron Fork.

We also found substantial differences in mean density and biomass of smallmouth bass and black bass compared to the estimates reported by Stark and Zale (1991) for Baron Fork and Glover River. In Baron Fork, Stark and Zale's 1991 estimates of small mouth bass numbers and biomass were 6 times higher (656 ± 1,109 *N*/ha, 95.8 ± 139.3 kg/ha) and black bass were nearly 4 times higher (683 ± 1,094 *N*/ha, 102 ±135.3 kg/ha) than our estimates (Table 1). Part of this discrepancy may reflect an extreme estimate they reported, which was 90% higher in density and 79% higher in biomass than their next lower estimate. In Glover River, Stark and Zale (1991) found smallmouth bass to be 9 times less abundant (12 ± 12 *N*/ha) with 11 times less biomass (1.7 ± 2.1 kg/ha) than we found (Table 1). Similarly, our estimates of black bass abundance (Table 1) were 2 times greater than Stark and Zale's (1991) estimates (63 ± 41 *N*/ha) but our lower biomass estimates indicate they found (9.7 ± 7.2 kg/ha) a greater proportion of large individuals.

Our abundance estimates for smallmouth bass in Baron Fork and Glover River were intermediate to those reported by Covington et al. (1983) for 2 Missouri Ozark streams (Jacks Fork River, 142 *N*/ha, and Current River, 44 *N*/ha) and slightly below those found by Paragamian and Coble (1975) in 2 Wisconsin streams (Plover River, 118 *N*/ha, and Red Cedar River, 132 *N*/ha). Biomass estimates for Baron Fork were similar to those for the 2 Wisconsin streams (Plover River, 17.5 kg/ha, and Red Cedar River, 15.1 kg/ha) and the Current River, Missouri (10.5 kg/ha), but are well below those reported for Jacks Fork River, Missouri (28.5 kg/ha). In Glover River, biomass was generally 2 to 4 times less (Table 3) than that reported for streams in Missouri and Wisconsin, supporting Stark and Zale's (1991) and our conclusion that this population consists mostly of young fish, with poor recruitment to older ages.

Age and Growth

Smallmouth bass in eastern Oklahoma streams are not long lived. We found maximum ages of 6 and 5 years for the Baron Fork and Glover River populations, respectively. Similarly, Orth et al. (1983) and Finnell et al. (1956) found no individuals over age 6 in Glover river; however, Stark and Zale (1991) collected 1 age-7 fish from the nearby Mountain Fork River in Oklahoma. In comparison, fish up to age 12 have been reported for stream populations of smallmouth bass in the northern and eastern part of the species' range (Carlander 1977).

Growth of age-1 through age-3 smallmouth bass in Baron Fork was slightly less than previous reports for this stream and its parent stream, the Illinois River (Stark and Zale 1991, Carlander 1977), but exceeded those for age-4 and age-5 fish (Table 3). This differs from Stark and Zale's (1991) hypothesis that because of poor growth rates in older ages, smallmouth bass populations in northeast Oklahoma streams may have reached their carrying capacity. Regionally, smallmouth bass of all ages in Baron Fork grew faster than those in Big Buffalo Creek, Missouri, but much slower than those in the Tennessee River, Alabama (Table 3).

Our estimates of smallmouth bass growth in Glover River can only be compared to estimates from other populations for ages 1 through 3 because of our low number of older-aged fish. Within these age groups, growth of smallmouth bass was similar to that reported by Orth et al. (1983) for age-1 and age-2 fish, but faster for age-3 fish. Stark and Zale 1991) found faster growing fish at all 3 ages in the Mountain Fork River, but they made 1 of their estimates below the impounded portion of this stream. Regulated flows have been shown to positively influence growth of smallmouth bass (King et al. 1991). As with the Baron Fork, our smallmouth bass growth estimates for Glover River were higher than those in Big Buffalo Creek, Missouri, and lower than those of the Tennessee river, Alabama (Table 3).

Mortality and Condition

Total annual mortality of smallmouth bass was intermediate in Baron Fork and high in Glover River compared with other studies. During 1994 and 1995, smallmouth bass mortality rates in Baron Fork were less than 60%. In contrast, mortality rates in Glover River exceeded 60% for both years, although our 1995 estimate of 88% was based on only 2 age classes. Fisher et al. (1997) reported a similar trend of higher natural mortality of smallmouth bass in Glover River (96%) than in Baron Fork (68%), based on 1994–1995 angler tag returns. Our estimates exceeded those reported for the Current River (40%) and Jacks Fork River (36%) in Missouri (Covington et al. 1983), but were similar to those in the Red Cedar River (55%) and Plover River (65%) in Wisconsin (Paragamian and Coble 1975).

Condition of fish in Baron Fork and Glover River, based on length-weight relationships, was either identical or nearly so during our study. These findings indicate similar well-being between the 2 populations (Everhart et al. 1975).

Management Implications

Management of black bass in eastern Oklahoma streams should account for regional differences in drainage basin characteristics and population attributes. Improvements in watershed land use practices will likely be needed to achieve fisheries management goals. Rutherford et al. (1987) reported that intensive silvicultural activities seemed to be the primary anthropogenic impact affecting the fish fauna in the Little River Basin of southeastern Oklahoma. In comparison, increased agricultural activities (poultry operations) have resulted in dramatic nutrient enrichment of water bodies in the Illinois River Basin (Nolen et al. 1989). Maintaining well-vegetated riparian buffer strips and proper road design and culvert maintenance will minimize sediment runoff into the stream from logging roads in Glover River and nutrient enrichment in Baron Fork. Possible benefits to the smallmouth bass fishery in Glover River and other streams within the Little River Basin might include increased production, lower natural mortality, and higher recruitment to older ages.

In conjunction with proper watershed management, efforts to improve stream habitat could be used to achieve management goals. Habitat maintenance and restoration methods for warmwater streams lag behind those for coolwater streams (Rabeni 1993); however, methodologies are similar and usually involve at least 1 of the following goals: reducing stream bank erosion and stream sedimentation, modifying channel morphology and alignment, and increasing stream cover (Lyons and Courtney 1990). Several areas of Baron Fork could benefit from efforts to reduce streambank erosion, and land, water and fish and wildlife management agencies should work with land owners to implement such projects. Fish passage in the Glover River could be improved by modification of existing or construction of new road culverts (Toepfer et al. 1999).

In addition to stream habitat management, regulations can benefit smallmouth bass fisheries by increasing biomass and improving the overall quality of fishing (Funk 1975). Fisher et al. (1997) reported high catch and harvest rates of smallmouth bass in Baron Fork but low rates in Glover River. In addition, angler exploitation of smallmouth bass was 30% higher in Baron Fork than in Glover River. Based on these findings, benefits to the smallmouth bass fishery in eastern Oklahoma streams could be realized more quickly, and with less expense, with appropriate harvest and length regulations, especially if there is sufficient angler cooperation, adequate enforcement, and periodic monitoring of smallmouth bass populations (Fisher et al. 1997). These comprehensive stream management goals can only be met through implementation of a management program that begins with planning and goal setting, allocates sufficient human and monetary resources, and coordinates cooperative efforts of affected landowners and natural resource agencies (Fisher et al. 1998).

Literature Cited

Ambrose, J. Jr. 1983. Age determination. Pages 301–324 *in* L. A. Nielsen and D. L. Johnson, eds. Fisheries techniques. Am. Fish. Soc. Bethesda, Md.

Balkenbush, P. E. 1996. Population biology, management, and sampling considerations for black bass and sunfish in two eastern Oklahoma streams. M. S. Thesis, Okla. State University, Stillwater. 147pp.

——— and W. L. Fisher. 1997. Fish sampling bias associated with stream access. Proc. Annu. Conf. Southeast. Assoc. Fish. and Wildl. Agencies 51:95–105.

Bovee, K. D., T. J. Newcomb, and T. G. Coon. 1994. Relations between habitat variability and population dynamics of bass in the Huron River, Michigan Natl. Biol. Surv., Biol. Rep. 21, Washington, D.C. 79pp..

Carlander, K. D. 1977. Handbook of freshwater fishery biology, vol. 2. Iowa State Univ. Press, Ames. 431pp.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. Univ. Calif. Publ. Stat. 1:131–160.

——— and D. S. Robson. 1960. The analysis of a catch curve. Biometrics 16:354–368.

Cleary, R. E. 1956. Observations of factors affecting smallmouth bass production on Iowa. J. Wildl. Manage. 20:353–359.

Covington, W. G., R. E. Marteney, and C. F. Rabeni. 1983. Population characteristics of sympatric smallmouth bass and rock bass in the Jacks Fork and Current rivers, Missouri. Trans. Mo. Acad. Sci. 17:27–35.

Everhart, W. H., A. W. Eipper, and W. D. Youngs. 1975. Principles of fishery science. Cornell Univ. Press, Ithaca, N.Y. 288pp.

Finnell, J. C., R. M. Jenkins, and G. E. Hall. 1956. The fishery resources of the Little River system, McCurtain County, Oklahoma. Okla. Fish. Res. Lab. Rep. 55, Norman.

Fisher, W. L., D. F. Schreiner, C. Martin, P. Balkenbush, E. Kessler, and J. Hegash. 1997. Evaluation of the smallmouth bass recreational fishery in eastern Oklahoma streams. Okla. Dep. Wildl. Conserv., Fed. Aid Sport Fish Restor. Grant F–41-R, Final Rep., Oklahoma City. 125pp.

———, A. F. Surmont, and C. D. Martin. 1998. Warmwater stream and river fisheries in the southeastern United States; are we managing them in proportion to their values? Fisheries. 23(12):16–24.

Frie, R. V. 1975. Measurement of fish scales and back-calculation of body lengths using a digitizing pad and microcomputer. Fisheries 7(6):5–8.

Funk, J. L. 1975. Evaluation of the smallmouth bass population and fishery in Courtois Creek. Pages 257–269 *in* R. H. Stroud and H. Clepper, eds. Black bass biology and management. Sport Fish. Inst., Washington, D.C.

Gablehouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. North Am. J. Fish. Manage. 4:273–285.

Jenkins, R. M., E. M. Leonard and G. E. Hall. 1952. An investigation of the Illinois River and pre-impoundment study of Tenkiller reservoir, Oklahoma. Okla. Fish. Res. Lab. Rep. 26, Norman. 136pp.

King, A. M., R. J. Graham, and W. S. Woolcott. 1991. Comparison of growth of smallmouth bass from two tributaries of the York River, Virginia. Pages 6–13 *in* D. C. Jackson, ed. The first international smallmouth bass symposium. Miss. Agric. For. Exp. Sta., Miss. State Univ., Starkville.

Leonard, E. M. and R. M. Jenkins. 1952. Growth of basses in the Illinois River, Oklahoma. Proc. Okla. Acad. Sci. 33:21–29.

Lyons, J. and C. C. Courtney. 1990. A review of fisheries habitat improvement projects in warmwater streams, with recommendations for Wisconsin. Tech. Bull. N 169, Wis. Dep. Nat. Resour., Madison. 34pp.

MacCrimmon, H. R. and W. H. Robbins. 1975. Distribution of the black basses in North America. Pages 56–66 *in* R. H. Stroud and H. Clepper, eds. Black bass biology and management. Sport Fish. Inst., Washington, D.C.

Marcher, M. V. 1969. Reconnaissance of the water resources of the Fort Smith quadrangle, east-central Oklahoma. Map HA-1, Okla. Geol. Surv., Norman. 1p.

——— and D. L. Bergman. 1983. Reconnaissance of the water resources of the McAlester and Texarcana quadrangles, southeastern Oklahoma. Map HA-9. Okla. Geol. Surv., Norman. 1p.

Nolen, S. L., J. H. Carroll, D. L. Combs, and J. C. Staves. 1989. Limnology of Tenkiller Ferry Lake, Oklahoma, 1985–1986. Proc. Okla. Acad. Sci. 69:45–55.

Orth, D. J., D. D. Oakey, and O. E. Maughan. 1983. Population characteristics of smallmouth bass in Glover Creek, south-east Oklahoma. Proc. Okla. Acad. Sci. 63:37–41.

Paragamian, V. L. and D. W. Coble. 1975. Vital statistics of smallmouth bass in two Wisconsin rivers and other waters. J. Wildl. Manage. 39:201–210.

Pflieger, W. L. 1975. Reproduction and survival of the smallmouth bass in Courtois Creek. Pages 231–239 *in* R. H. Stroud and H. Clepper, eds. Black bass biology and management. Sport Fish. Inst., Washington, D.C.

Rabeni, C. F. 1993. Warmwater streams. Pages 427–443 *in* C. C. Kohler and W. A. Hubert, eds. Inland fisheries management in North America. Am. Fish. Soc., Bethesda, Md.

Reed, M. S. and C. F. Rabeni. 1989. Characteristics of an unexploited smallmouth bass population in a Missouri Ozark stream. North Am. J. Fish. Manage. 9:420–426.

Ricker, W. E. Computation and interpretation of biological statistics of fish populations. Fish. Res. Bd. Can. Bull. 191.

Rutherford, D. A., A. A. Echelle, and O. E. Maughan. 1987. Changes in the fish fauna of the Little River drainage, southeastern Oklahoma. 1948–1955 to 1981–1982; a test of the hypothesis of environmental degradation. Pages 178–183 *in* W. J. Mathews and D. C. Heins, eds. Community and evolutionary ecology of North American stream fishes. Univ. Okla. Press, Norman.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. 2nd ed. Macmillan Publ. Co., New York.

Smith, J. 1982. A 1982 Illinois River fisheries survey compared to previous Illinois River fisheries surveys. Okla. Dep. Wildl. Conserv., Northeast. Reg. Off. Misc. Rep., Porter. 82pp.

Stark, W. J. and A. A. Echelle. 1998. Genetic structure and systematics of smallmouth bass, with emphasis on interior highland populations. Trans. Am. Fish. Soc. 127:393–416.

——— and A. V. Zale. 1991. Status of smallmouth bass populations in eastern Oklahoma. Okla. Dep. Wildl. Conserv., Fed Aid Proj. F-41-R, Final Rep., Oklahoma City. 43pp.

Toepfer, C. S., W. L. Fisher, and J. A. Haubelt. 1999. Swimming performance of the threatened leopard darter in relation to road culverts. Trans. Am. Fish. Soc. 128:155–161.

Weathers, K. C. and M. B. Bain. 1992. Smallmouth bass in the shoals reach of the Tennessee River; population characteristics and sport fishery. North. Am. J. Fish. Manage. 12:528–537.

Zar, J. H. 1984. Biostatistical analysis, second ed. Prentice-Hall, Inc., Englewood Cliffs, N.J. 718pp.